ACCESS NUMBER: 31105

STUDY TITLE: A Study of Currents at 900 m Depth and Temperatures for Depths ≲ 900 m in the Open Gulf of Mexico using 1998-2002 PALACE Data

REPORT TITLE: Intermediate Depth Circulation in the Gulf of Mexico: PALACE Float Results for the Gulf of Mexico Between April 1998 and March 2002

CONTRACT NUMBER: MMS 1435-01-00-CT-31105

SPONSORING OCS REGION: Gulf of Mexico

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KEY WORDS: Eastern Gulf; Western Gulf; PALACE floats; drifters; temperature profiles; Loop Current; bottom boundary layer; Princeton model; Mercator model.

BACKGROUND: 17 PALACE floats were set in the Gulf of Mexico in 1998 as part of a study of the Gulf of Mexico by the National Oceanographic Partners Program (NOPP). These floats were programmed to drift at about 900 m depth to give information about the currents at this depth and to profile temperature as they surfaced once a week to be tracked by satellite. When funding for the NOPP program was not renewed, MMS agreed to support the completion of the analysis of the PALACE float data. This is a study of that float data.

OBJECTIVES: (1) To estimate the 900-m depth mean circulation in the Gulf of Mexico using PALACE float data and use established methods to estimate when and where the flow is statistically significant; (2) To compare PALACE deep drift and temperature data with satellite altimeter data to if, when and how surface features penetrate down to 900 m depth; (3) To look

for evidence of sub-surface eddies in deep drift and temperature data from PALACE floats and to use satellite data to see that the deep eddies had surface signatures; (4) To examine PALACE temperature profiles for seasonal changes in the surface layer, vertical displacement of isotherms in the thermocline due to the presence of the Loop Current, Loop Current rings, and cold core rings, and for evidence of anything unusual or unexpected; (5) To obtain computer model output for comparison with the PALACE inferred flows.

DESCRIPTION: The PALACE float data consisted of listings of satellite surface fixes of the location of each float when they were at the surface for about 12 hours once a week plus temperature profile data each float obtained as it rose to the surface along with some diagnostic information such as depth at which the floats supposedly drifted. From the data we produce two data sets: (1) Estimates of the ≈ 900 m depth currents in the open Gulf of Mexico and (2) Temperature profiles in the open Gulf of Mexico. To get the former we culled out drifts of floats which had settled to the bottom in water which was shallower than their programmed deep drift depths. We excluded the drifts which occurred when the floats made their weekly ascents and descents to and from the surface when we made the estimates of the ≈ 900 m depth currents. To get the temperature data set we excluded those temperature profiles made in water shallower than 200 m. We also found that the floats yielded bad temperature data as their batteries started to fail as they approached their expected life expectancy and we excluded these data. The floats were launched in the northern Gulf of Mexico but soon dispersed throughout the Gulf with only one escaping from the Gulf. The last float stopped working in March 2002. So ≈ 900 m depth currents and temperature profiles were obtained through out the Gulf of Mexico over the 4-year period 1998-2002.

SIGNIFICANT CONCLUSIONS: There appears to be little communication at ≈ 900-m depth between the eastern and western Gulf of Mexico. 900 m depth is not a level of no motion in the Gulf of Mexico either in an "instantaneous" 6-day average or longer term average sense. At this depth there is a mean cyclonic flow along the borders of the Gulf of Mexico, and this flow intensifies into a relatively strong, 10 cm/s, southward flowing current in the western Bay of Campeche. Evidence of coastal, riverine water in the open Gulf of Mexico is much more common than previously thought. Half of the temperature profiles examined showed evidence of such water. This riverine, coastal water was more common in the winter than in the summer, and appears consistent with LATEX drogued drifter results.

For PALACE floats drifting set to drift at ≈ 900-m depth with seven-day cycle times in the Gulf of Mexico: (1) One must not include the drifts the floats experience while at the surface and while cycling to and from the surface when estimating their deep drifts. Not excluding them would yield to erroneous deep-drift estimates. (2) Because about 30% of the Gulf of Mexico is shallower than 900 m, on many cycles the floats will settle on the bottom rather than freely drift at ≈ 900 m depth. One must be sure to exclude all deep drift estimates made for regions where the water depth < 900 m. (3) Because of the large variability of the currents with time, more than five estimates must be used in estimating meaningful average currents.

STUDY RESULTS: Approximately 1300 estimates of the flow at ≈ 900 m depth, each an average over $6\,1/2$ days, were obtained through out the Gulf of Mexico between April 1998 and March 2002. The individual current measurements showed that the current speed and direction were highly variable in time throughout the Gulf of Mexico. The average speed at that depth

was 5 cm/s with the strongest flows attaining values approaching 25 cm/s (≈ 1/2 knot). The study indicates that 1/2° latitude by 1/2° longitude averages of the velocities were statistically significant provided more than 5 values were used to form the averages. The cyclonic flow pattern around the borders of the Gulf of Mexico was diverted in the southern Bay of Campeche around the Campeche Bump, a relic delta-like bottom feature there. Three persistent cyclonic gyres with diameters ranging from ≈ 100 km to ≈ 300 km were seen; one was in the Bay of Campeche, another just north of the Bay of Campeche, and the third off of western Louisiana. The mean currents at ≈ 900 m depth and some numerical model mean results from comparable depths compared favorably.

About 1500 temperature profiles, from ≈ 900 m depth up to the surface, were obtained throughout the Gulf of Mexico over the same period. These profiles indicated that coastal waters are commonly found near the surface throughout the open Gulf of Mexico being more common in the winter and less common in the summer.

Warmer profiles, together with stronger deep currents, were seen when satellite altimeter data indicated the Loop Current or a Loop Current ring were overhead suggesting that these features extend down in to ≈ 900 m depth. However, the flow direction at ≈ 900 m depth was consistent with deep extensions of overhead, anticyclonic Loop Current and Loop Current rings in only about half the cases.

Sub-surface cold eddies of diameter ≤ 100 km were seen and tracked moving westward at ≈ 3-5 cm/s. The top of these eddies were at 200 m to 300 m depth. At ≈ 900 m depth the orbital currents ≈ 10 cm/s and indicated cyclonic rotation. One set of observations suggested that some of these sub-surface eddies may be decapitated forms of cyclonic eddies with a surface expression formed in the northeastern Gulf of Mexico.

Deep, ≈ 50 m-150 m, surface mixed layers were common in the open Gulf of Mexico in the winter particularly in the Loop Current and in Loop Current rings indicating enhanced heat loss in the Gulf of Mexico in the winter if the Loop Current and/or Loop Current rings are present. The temperature data showed that in the thermocline there was more variability in temperature than in the surface layer, and that in the thermocline vertical displacements ≈ 600 m occurred for some of the colder isotherms.

STUDY PRODUCTS: Weatherly, G., N. Wienders, and R. Harkema, 2003. Temperature inversions in the open Gulf of Mexico. *J. Geophys. Res.* **108**, doi:10.1029/2002JC001680.

Weatherly, G. Intermediate Depth Circulation in the Gulf of Mexico: PALACE Float Results for the Gulf of Mexico Between April 1998 and March 2002, OCS Study MMS 2004-013, U. S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. 51 pp.